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Experimental Study of Torsional Reinforcement in R.C. Slab with Four Edges Discontinuous

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Abstract— The twisting moments can become significant at points along the slab diagonals and the variation of principal moments is along and across a diagonal of simply supported and uniformly loaded square slab of homogeneous material, as obtained from an elastic analysis. If downward reactions cannot be developed at the supports, the corners will be lifted up. By providing torsion reinforcement, corners are usually prevented from being lifted up. In such cases the corners have to be suitably reinforced at top and also at bottom otherwise cracks are liable to be formed at the corners. The present investigation is intended to study the influence of torsion reinforcement in reinforced concrete slab with end condition all ends discontinuous under uniformly distributed load. Slabs with torsion reinforcement varying from 20% to 35% were casted and tested. Increasing in the torsion reinforcement controls the deflection of the slab element. As the torsion reinforcement increases the corners are being held down. At the maximum of 35% of main reinforcement was provided as torsion reinforcement corners are not held down completely and there is a considerable decrease in central deflection also.

Index Terms— Torsion reinforcement, central deflection, Slabs

I. INTRODUCTION

Concrete slabs are widely in use as floors not only in industrial and residential buildings but also as decks in bridges. The big advantage is flexibility in methods of manufacturing. They can be made in-situ as well as prefabricated and brought to construction site in full scale.
Two-way slabs system is more aesthetic than the other one and is easier to construct due to less framework. When long span by short span ratio is less than 2 it is said to be two way slabs. The bending moment induced by the uniformly distributed load is resisted by the tension reinforcement provided in the bottom of the slab. The central deflection is controlled by the tension reinforcement. By providing torsion reinforcement, corners are usually prevented from being lifted up. In such cases the corners have to be suitably reinforced at top and also at bottom otherwise cracks are liable to be formed at the corners. The torsion reinforcement is provided in form or layers of reinforcement space at required interval to a distance of 1/5 of the span of the slab form the corner of the slab. The present investigation is intended to study the influence of torsion reinforcement in reinforced concrete slab with end condition all ends discontinuous under uniformly distributed load. For the present work, slabs with torsion reinforcement varying from 20% to 35% of the main reinforcement required for short span bending moment were casted and tested. By varying torsion reinforcement the corner lift was measured.

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II. EXPERIMENTAL WORK

Slabs with various torsion reinforcement were cast using M20 grade of concrete.

2.1 Materials and Concrete mix

Ordinary Portland cement of 53 grades of specific gravity 3.15 was used for all the specimens cast. The Fine Aggregate used for casting was clean river sand and it was clean and dry. The specific gravity of fine aggregate was 2.71. The fineness modulus of the fine aggregate was 2.4.
The coarse aggregate used was broken granite-crushed stone of size 10 mm. The specific gravity of coarse aggregate was 2.84. The bulk density of coarse aggregate was found to be 1640 kg/m^3. Potable water available in the structural engineering laboratory was used for casting all specimens of this investigation. The quality of water was found to satisfy the requirements of **IS-456 -2008.** 1: 1.5: 3 mix proportion was adopted. Weight batching was adopted. For every 50 Kg of cement 75 Kg of sand and 150 Kg of coarse aggregate were used. Water cement ratio of 0.5 was adopted as hand compaction was done. To improve the workability of concrete this water cement ratio was adopted. For each batch of mixing 25 liters of water was added. Reinforcement confirming to IS: 1786 were used as reinforcing rods. Main reinforcement of 6 mm diameter was used. Weld mesh of 3 mm diameter with was used as torsion reinforcement. Concrete cubes of 150mm x 150mm x 150 mm size are casted and tested before the testing of slab. Steel moulds were used in casting these companion specimens.

2.2 Design Details

The size of the square slab specimens was 1500 mm x 1500 mm x 60 mm (thickness). The reinforcement was provided in the form of 6 mm diameter Grade I steel 125 mm centre to centre spacing. The clear cover to the reinforcement is 15 mm. The reinforcement details are shown in Fig. **2.2**. The descriptions of the square slabs are shown below.

TABLE 2.2 DESCRIPTION OF THE SPECIMEN

Sl. No.	Description of the specimen	% of torsion reinforcement
1	Slab 1	0
2	Slab 2	20
3	Slab 3	25
4	Slab 4	30
5	Slab 5	35
6	Slab 6	75

Minimum Reinforcements are provided in the form of 6 mm diameter Grade I steel having yield strength of 252 N/mm^2 is used as a main reinforcement and both 6 mm diameter Grade

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I steel and weld mesh made up of mild steel of yield strength of 250N/mm^2 are used as torsion reinforcement. Description of the specimen is shown in the table 2.2

FIG.2.2. REINFORCEMENT DETAILS

2.3. CASTING AND CURING OF SPECIMENS

2.3.1. Preparation of concrete mix

Predetermined quantities of the constituent materials of RCC were weighed using a 300 Kg platform balance. Cement and sand were mixed first then the coarse aggregate was added and the materials were mixed thoroughly until uniformity was achieved. Then the required quantity of water was added slowly and wet mixing was done. Wet mixing was completed within 5 minutes.

2.3.2. Casting of slabs

A paper was spread on the cleaned and surface leveled solid concrete floor of the laboratory. On this paper the 60 mm depth wooden mould of slab was placed. The inner sides of the mould were oiled so as to avoid the adhesion of cement mortar. The reinforcement was placed inside the mould on the cover blocks which were made of cement mortar of 1:2 mixes. The fresh reinforced concrete was put inside the mould in convenient layers and was compacted by compaction rod and the surface was made plane by toweling. The corner provide with full torsion reinforcement was marked.

2.3.3. Casting of companion specimens

The inner surfaces of the moulds were cleaned thoroughly just before casting and a thin coat of oil was applied to this surface to avoid the adhesion of cement mortar.
For casting the standard specimens, moulds were filled with concrete in 3 layers. Each layer was well compacted by standard steel rod. The following companion specimens were cast along with each slab.
Cubes of 150mm size - 3 Nos. per batch.
These specimens were removed from the moulds 24 hours after casting.

2.3.4. Curing of R.C.C slabs

The slabs were removed from mould twenty four hours after casting and were cured under wet gunny bags over 28 days. The gunny bags were watered twice a day, taking special care to see that all parts were watered uniformly.

2.3.5. Curing of companion specimens

The companion specimens were removed from mould twenty four hours after casting and all the specimens were kept near the slab and were cured under wet gunny bags, along with the slabs. Thus the same curing conditions were adopted for both the slabs and their companion specimens.

2.4. TESTING AND INSTRUMENTATION

2.4.1 Preparation of specimens before testing

Each specimen was removed from the curing yard in the previous day of the day of testing manually and it was white washed. Then the slab was lifted and erected in position for testing.

2.4.2 Loading frame

The slabs were tested in a 100 ton capacity self straining loading frame. The applied jack load was measured by means of proving ring of 15 ton capacity**.** The magnitude of the applied load was obtained from the calibration chart of the proving ring.

2.4.3 Test set up

The test set up is shown in Figs 2.4.3. Each slab was simply supported on framework made of ISMC 300 with 10cm bearing on all the sides while the corners of the channels were supported by concrete cubes of size 150 mm x 150 mm x 150 mm. Three concrete cubes were placed as a column to raise the frame work to a height of 450 mm so that we can fix the LVDT under the slab to measure the central deflection of the slab.
In uniformly distributed load, top surface of the slab was filled with sand to a height of 10cm to have uniform distribution of load on the slab. Over the sand filling, cubes were arranged in pyramidal shape. Load was applied through mechanically operated hydraulic jack of capacity 15 ton on the top layer of the cubes. To avoid the punching effect of the hydraulic jack, steel plates were used.

FIG.2.4.3 TEST SETUP

2.4.4 Measurement of deflections

The central deflection was measured by LVDT fixed at centre of the slab in the bottom region. And the corner lift was measured by the dial gauges of least count 0.01.

2.4.5 Marking of the first crack

Crack patterns were observed manually during loading. The first crack was noted and the place where it initiated was marked. The corresponding loading was also noted down.

2.4.6 Marking of the crack patterns

The slab was removed immediately after the testing and the crack lines were marked.

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2.4.7 Testing on companion specimens

Cubes of size 150mm that had been cast along with the slabs were tested on the same day on which the respective slabs were tested to ascertain the compressive strength of the concrete used in the slabs. The cube test were carried out in a Compression Testing machine of 300 tone capacity and these tests were carried out as per IS code recommendation.

III. RESULTS AND DISCUSSION

The corresponding corner uplift and central deflection were noted for each incremental load upto ultimate load and the results were plotted. The behavior of torsion reinforcement from 20% to 35% was compared with 0% and 75% and the graphs were plotted. The average cube compression strength attained from the companion specimens tested was 24.35 N/mm^2.

3.1. TEST SPECIMENS

The results obtained from the test specimens were plotted in the graph. Fig.3.1 to 3.3 shows the load vs. corner lift of slab with torsion reinforcement. Uplift of corner starts at a load of 0.8 KN/m^2. Maximum uplift was obtained at ultimate loads.

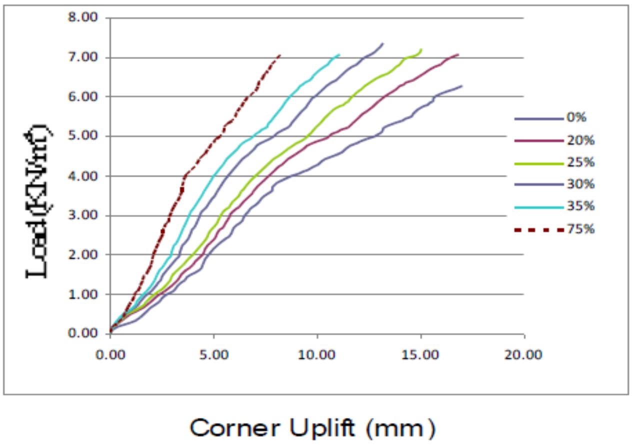

Figure 3.1 Load Vs Corner Uplift at Corner A

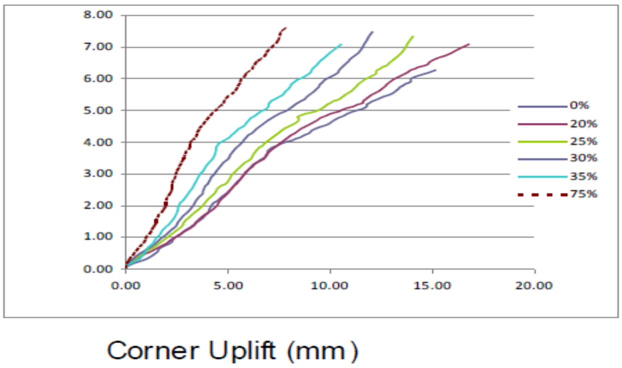

Figure 3.2 Load Vs Corner Uplift At Corner B

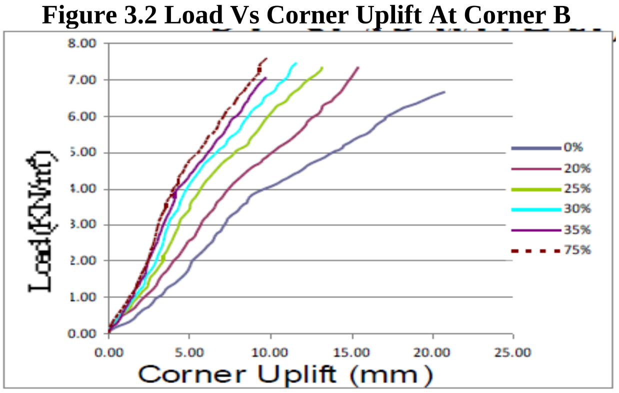

Figure 3.3 Load Vs Corner Uplift at Corner C

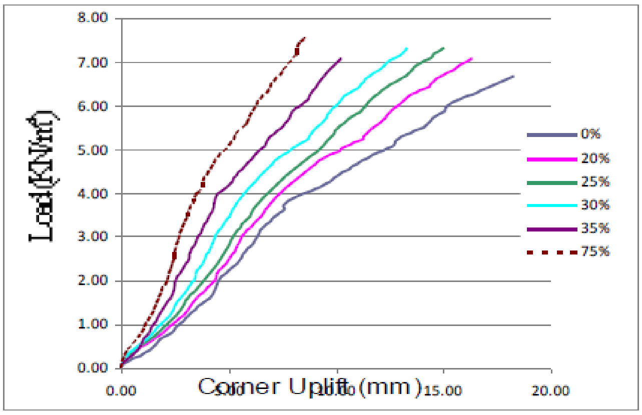

Figure 3.4 Load Vs Corner Uplift at Corner D

Fig 3.4 shows the load vs. central deflection of slab with torsion reinforcement. Maximum central deflection of 28.76 mm was reached at failure load. As the percentage of torsion reinforcement increases there was corresponding decrease in central deflection.

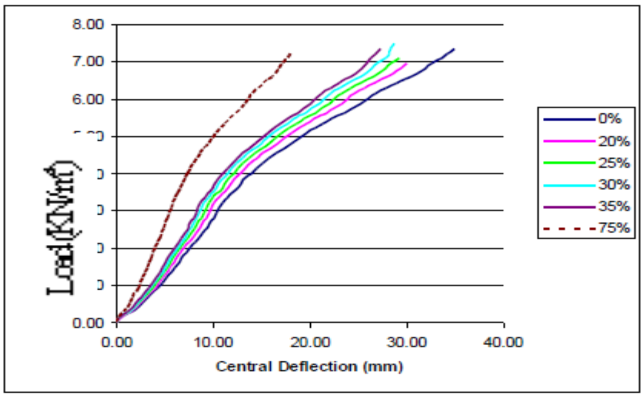

Figure 3.5 Load Vs Central Deflection

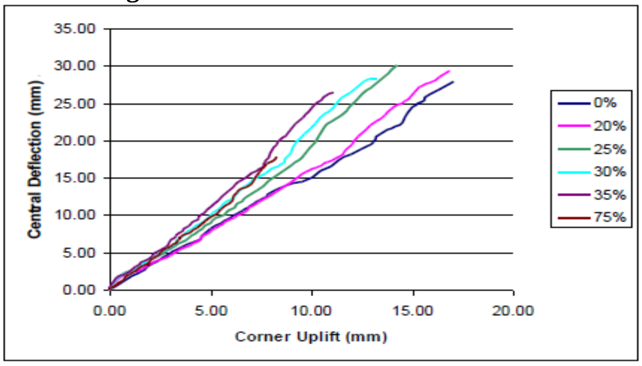

Figure 3.6 Central Deflection Vs Corner Uplift at Corner A

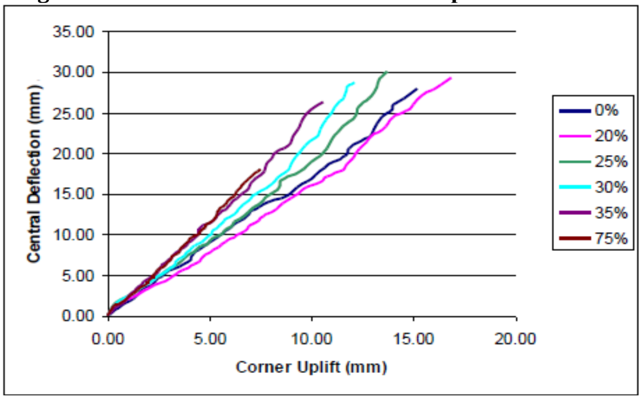

Figure 3.7 Central Deflection Vs Corner Uplift at Corner B

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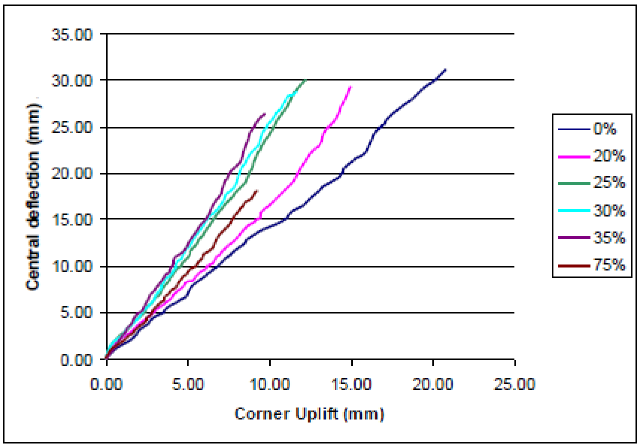

Figure 3.8 Central Deflection Vs Corner Uplift at Corner C

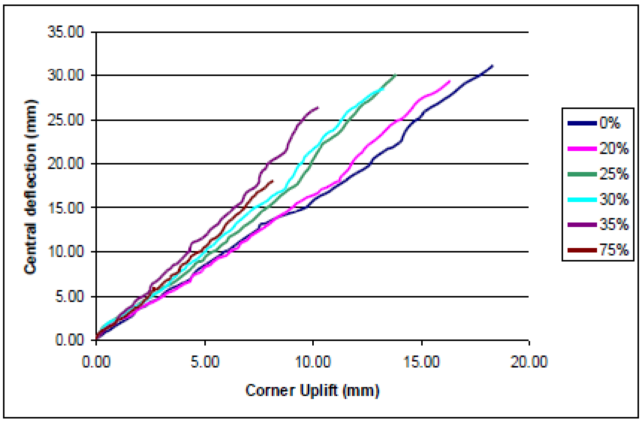

Figure 3.9 Central Deflection Vs Corner Uplift at Corner D

The graph is plotted between corner uplift and central deflection and it found to be linear. This is shown in the figure 3.5 to 3.7. Figure 3.6 shows the cracks observed at the bottom surface of the specimen.

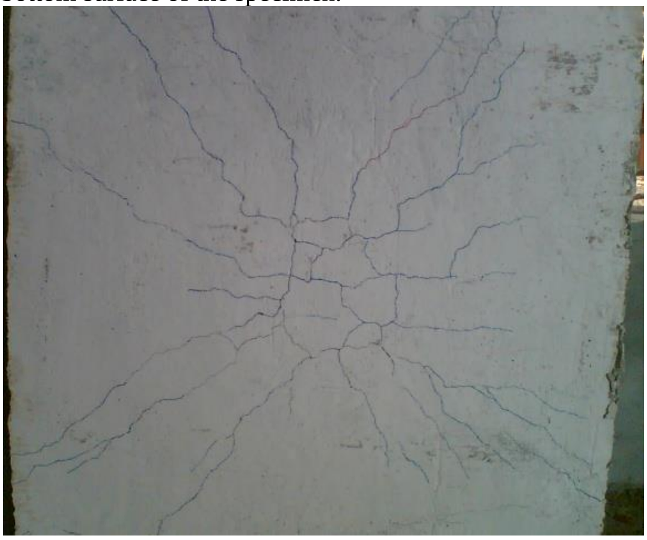

Figure 3.10 Crack Pattern in the Bottom Surface

3.2 Discussion

As per the code the torsion reinforcement provided will be 75% of main reinforcement at free edges and 50% of this reinforcement should be carried out to other discontinuous edge. As compared to the solid slab, with increase in the percentages of torsion reinforcement, there is a reduction in the central deflection and the corner uplift, but when the percentages of torsion reinforcement increases; the load carrying capacity of the slab also increases. By providing additional torsion reinforcement the load carrying capacity of the slab increases. Simply supported slab without torsion reinforcement were casted and tested and the corner uplift and central deflection were compared with the slabs with various percentages of torsion reinforcement.

While providing 75% of torsion reinforcement it was observed that the central deflection was about 47% whereas at 35% of torsion reinforcement the central deflection was about 30%. While providing 75% of torsion reinforcement it was observed that the corner uplift about 58% whereas at 35% of torsion reinforcement the corner uplift was about 47%. There may be a considerable decrease in deflection when higher percentage of torsion reinforcement is provided between 35% and 75% will be economical.

For all edges discontinuous, by varying the percentage of torsion reinforcement from 20% to 35%, the uplift and central deflection will be observed to be decreasing. By increasing the percentages of torsion reinforcement uplift is reduced.

IV. CONCLUSIONS

Slabs with torsion reinforcement varying from 20% to 35% were casted and tested. Increasing in the torsion reinforcement controls the deflection of the slab element. The corners are being held down based upon the quantity of torsion reinforcement provided. As the torsion reinforcement increases the corners are being held down. Increasing in the torsion reinforcement controls the deflection of the slab element. At the maximum of 35% of main reinforcement was provided as torsion reinforcement corners are not held down completely. Due to increase in torsion reinforcement there is a considerable decrease in central deflection also.

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